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A hybrid data assimilation framework for robust hydrologic forecasting

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Data Assimilation (DA) has garnered attention by the researchers from different disciplines in hydro-geosciences as an effective tool to improve model predictions in non-linear and non-Gaussian dynamical systems. In this work, we combine the advantages of two prominent DA approaches, the Particle Filter (PF) and 4D-VAR, to formulate a robust DA algorithm to assimilate both states and parameters of hydrological models. In the proposed model, we formulated the sequential PF within the variational 4D-VAR scheme. The use of 4D-VAR allows to update the prior (background) error covariance matrix throughout the assimilation process, leading to better estimation of posterior probability distribution. In this framework, we separate the prior error covariance matrix into two different matrices: static prior error covariance (defined by 4DVAR), and dynamic prior error covariance. However, dynamic prior error covariance is updated from cycle to cycle over the main assimilation time period. The updated error covariance in one window is used as the prior error covariance for the next window thus better capturing the error of the hydrological cycle. Therefore, the updated covariance in each assimilation window enables the 4DVAR c ost function to better estimate the initial condition and reduce the uncertainty at initial point of each assimilation window, which consequently enhances the quality of assimilation process. The premise of this approach is that the particle degeneracy and sample impoverishment problems are dramatically mitigated and the predictive results are considerably increased. The proposed method is applied on both conceptual and highly non-linear hydrologic models and the effectiveness, robustness and reliability of the method is demonstrated for few river basins across the United States.